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(54) Heat exchangers and dephlegmators

(57) A heat exchanger includes a multiplicity of vertical, elongate, generally parallelapipedal boiling or mass transfer channels 4, each having a pair of main vertical walls defined by vertical plates 2 down which liquid is able in operation to flow. At least one of the channels 4 has at least one wave-shaped member or finning 14 dividing it into a multiplicity of vertical sub-channels 18. In addition at least one of the plates 2 has at least one vertical row of buffles or dimples 12 extending into at least of the sub-channels 18. Each baffle or dimple 12 engages finning 14 at both corner regions of a sub-channel 18 defined between a plate 2 and the finning 14.

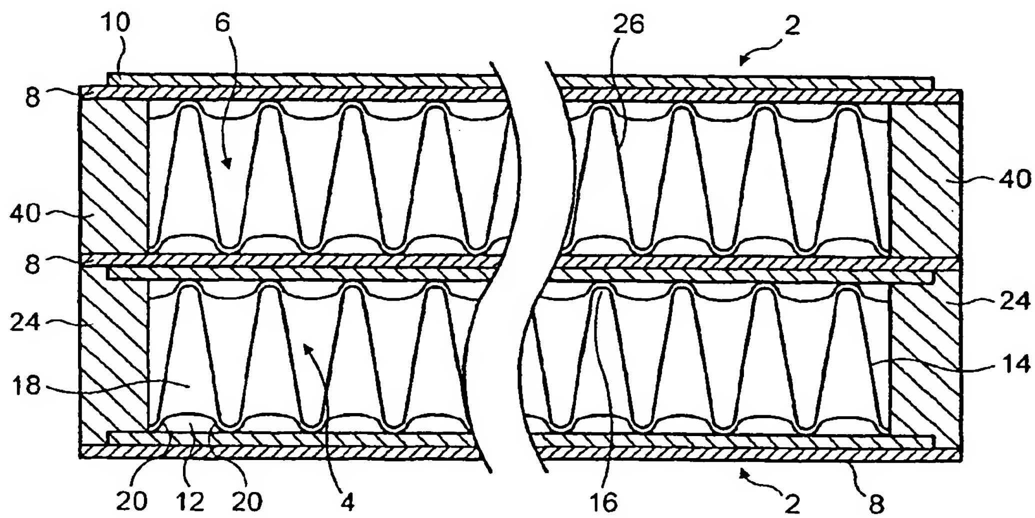

FIG. 5

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Description

[0001] This invention relates to heat exchangers, in particular to heat exchangers suitable for use in boiling a liquefied gas, such as liquid oxygen, or as dephlegmators for the separation of a gas mixture such as air.

[0002] Boilers or reboilers of a liquefied gas such as oxygen have conventionally been of the so-called thermosiphon kind in which the boiling passages are at least partially immersed in a volume of the liquefied gas. Heat provided by a condensing gas causes bubbles of vapour to form in the liquefied gas in the boiling passages. As a result, siphoning of the liquefied gas occurs. A disadvantage of such reboilers is that the effect of the liquid head in the boiling passages requires there to be a greater average temperature difference between the condensing gas and the boiling liquefied gas then would otherwise be necessary. In, for example, a reboiler-condenser which thermally links the lower pressure column to the higher pressure column of a double rectification column used in the separation of air, the greater average temperature difference translates into a small but appreciable increase in the power consumed by the total air separation process. Accordingly, rather than utilising a thermosiphoning upward flow of the liquefied gas, so-called downflow reboilers are gaining in popularity. Fins, i.e. wave-shaped members, are used in the boiling passages so as to enhance the rate of heat transfer. It is found that in such downflow reboilers there is a problem in obtaining uniform rates of boiling at different locations within the reboiler. The cause of this problem has generally been attributed to an uneven distribution of the liquid at the top of the heat exchanger. Various different solutions to this problem have been proposed. See, for example, US-RE-33026, EP-A- 0 780 646 and EP-A- 0 797 065. Even with an improved distribution of the liquefied gas at the top of the heat exchanger, the problem, although somewhat reduced, still quite decidedly remains. In a reboiler-condenser for boiling oxygen which thermally links the top of the higher pressure column to the bottom of the lower pressure column in a double rectification column, the problem manifests itself in a design of heat exchanger in which only a part, typically in the order of 50%, of the liquefied gas fed through the boiling passages is successfully vaporised, with the result that liquid oxygen typically needs to be pumped back to the top of the heat exchanger, thus adding to the total amount of work required to separate the air and the capital cost of the plant. The boiling of oxygen is particularly difficult because if any heat exchange surface on which boiling normally occurs becomes dry, an explosion hazard is created.

[0003] The problem also arises when the heat exchanger is used as a dephlegmotor. In this instance the problem manifests itself in a disproportionately large heat exchanger for the heat exchange and separation duties that it has to perform.

[0004] It is therefore an aim of the present invention to provide a heat exchanger of the downflow boiling kind (that is to say, a heat exchanger comprising a multiplicity of vertical, elongate, generally parallelapipedal boiling or mass transfer channels each having a pair of main vertical walls down which liquid is able, in operation, to flow, wherein at least one of the said boiling or mass transfer channels has therein at least one wave-shaped member dividing the channel into a multiplicity of vertical sub-channels, each apex of the said wave-shaped member engaging an abutting main vertical wall) which ameliorates the above-mentioned problem.

[0005] According to the present invention there is provided a heat exchanger comprising a multiplicity of vertical, elongate, generally parallelapipedal boiling or mass transfer channels each having a pair of main vertical walls down which liquid is able, in operation, to flow, wherein at least one of the said boiling or mass transfer channels has therein at least one wave-shaped member dividing the channel into a multiplicity of vertical sub-channels, each apex of the said wave-shaped member engaging an abutting main vertical wall, characterised in that at least one of the vertical walls has at least one vertical row of vertical baffles or dimples extending into at least one of the sub-channels, each baffle or dimple having a shape such that it engages the said wave-shaped member at both the sub-channel corner regions defined between the main vertical wall from which the baffle or dimple extends and the said wave-shaped member itself. As a result downward flow of liquid in the corner regions is obstructed.

[0006] The obstruction of downward flow of liquid in the corner regions is advantageous because it results in the liquid finding other flow paths and thereby counteracts to some extent a propensity for the liquid to be drawn into the corners. It is as a result of the phenomenon of forces of surface tension and gravity drawing the liquid into the corners that liquid flow rates which would otherwise have been sufficiently large to prevent localised thinning of surface films to the point of dryness have in fact been found to be inadequate in known heat exchangers of the kind referred to hereinabove. Preferably, therefore, there is a vertical row of the said baffles or dimples extending into each sub-channel. It is similarly preferred that there is a first row of said baffles or dimples extending into each sub-channel from one of the main vertical walls thereof, and a second row of said baffles extending into an adjacent sub-channel from the other main vertical wall thereof. Further, in order to obtain the best possible obstruction of the liquid, each baffle or dimple preferably makes a sealing engagement with the said wave-shaped member at both the said sub-channel corner regions.

[0007] Preferably, so as to avoid excessive hold-up of liquid flow, the baffles are inclined at an angle in the general direction of liquid flow. Typically, each baffle may make an angle in the range of 45 to 90° to the vertical wall from which it extends.

[0008] Preferably, for ease of manufacture, the baffles

or dimples in each row are uniformly spaced apart, and all the baffles or dimples are of identical size and shape, and in the case of baffles at the same angle to the general direction of liquid flow.

[0009] Since the forces of surface tension and gravity that tend to draw the liquid into the corners are quite strong, the baffles or dimples are preferably relatively closely spaced, being typically in the range of 4 to 10 mm apart.

[0010] In one embodiment of the heat exchanger according to the invention the main vertical wall comprises a first base sheet bonded to a complementary second sheet or array of second sheets, wherein the baffles extend from the second sheet. Such an embodiment is advantageous in that it enables the baffles to be preformed by stamping tabs out of the second sheet or sheets. An advantage of employing dimples is that they can be pre-formed by stamping in a wall comprising a single sheet, thus avoiding a double sheet construction. Another advantage of a single sheet construction is that it avoids any risk of penetration of liquid between sheets that are bonded together.

[0011] Typically, baffles or dimples in a row extending from any particular main vertical wall may be staggered in relation to the baffles or dimples in a neighbouring row extending from that vertical wall. Similarly, the rows in any main vertical wall may be staggered in relation to the rows in the opposite main vertical wall.

[0012] Preferably, the boiling or mass exchange passages are arranged alternately with passages through which a condensable gas is able to be passed, so as to enable heat to be supplied to the boiling or mass exchange passages, and the gas to be condensed. (Other arrangements of the respective passages than strict alternation are, however, possible, although not preferred.) The boiling and condensing passages therefore share common walls.

[0013] The exchanger according to the invention is preferably of the plate-fin kind. In a plate-fin heat exchanger according to the invention, the plates provide the said walls, and the fins provide the wave-shaped members. A plate fin heat exchanger according to the invention may be formed as a unitary article by assembling and vacuum brazing its constituent parts.

[0014] The heat exchanger according to the invention is particularly suited for use as a condenser-reboiler placing the top of the higher pressure column in heat exchange relationship with the bottom of the lower pressure column of a double rectification column for use in the separation of air by rectification at cryogenic temperatures. It is also suitable for use as a dephlegmator in the separation of air or other gaseous mixtures.

[0015] Plate-fin heat exchangers according to the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a first schematic section through a first embodiment of a heat exchanger illustrating boiling and condensing passages;

Figure 2 is a sectional diagram of a region of one of the boiling passages, the region being surrounded by the ring X shown in Figure 1;

Figure 3 is a second schematic section through the heat exchanger, taken along line III - III of Figure 1, illustrating a single boiling passage;

Figure 4 is a third schematic section through the heat exchanger, taken along line IV - IV of Figure 1, illustrating a single condensing passage;

Figure 5 is a plan-section view of the heat exchanger, illustrating a pair of passages, one boiling, the other condensing; and

Figure 6 is a diagram similar to Figure 2 showing an alternative embodiment of a heat exchanger.

[0016] The drawings are not to scale.

[0017] Referring to Figures 1 to 5 of the drawings, the heat exchanger includes an array of vertical plates 2, equally spaced apart from one another, and defining alternate boiling passages 4 and condensing passages 6. The vertical plates 2 are made of a metal or alloy which is good heat conductor (for example, aluminium) and therefore enable, in use, heat to be exchanged from a condensing gas to a boiling liquid. Although only ten plates 2 are shown in Figure 1, this is for purposes of ease of illustration and, in practice, a plate fin heat exchanger for use as a condenser-reboiler in a double rectification column may have at least one hundred plates, and thus the same number (less one) of passages.

[0018] With particular reference to Figures 2 and 5, each plate 2. except for the two outermost ones, comprises a first sheet 8 to which are bonded a plurality of second sheets 10 arranged end-to-end in a vertical array. Each second sheet 10 is disposed on the boiling passage 4 side of the first sheet 8 to which it is bonded. Each second sheet 10 has a vertical row of baffles 12 in the form of downwardly extending tabs that are integral with the sheet 10 and which may simply be formed by being punched out of the sheet 10 by an appropriately shaped tool. Each baffle 12 typically forms an angle of 60° with the sheet 10. As shown in Figure 1, the outermost plates 2 are both of one piece formation, and are somewhat thicker than the rest of the plates for purposes of providing more strength to the heat exchanger.

[0019] Typically, each of the plates 2 that are formed of a first sheet 8 and a plurality of second sheets 10 has a thickness in the range of 0.8 to 2.0 mm, preferably in the range of 1.0 to 1.5 mm. The second sheets 10 are preferably all identical to one another and each one typically has the same thickness as the sheet 8 to which it is bonded. Typically, each sheet has a height in the range of 150 to 500 mm. In a typical heat exchanger in

accordance with the invention, each array of second sheets 10 may have from 10 to 20 members. It is preferred to employ such an array of second sheets 10 to form a plate 2, because a single, and therefore particularly elongate, sheet 10 would typically have thousands of baffles 12 and would therefore be difficult to handle during manufacture of the heat exchanger. Each boiling passage 4 contains finning or wave-shaped members 14 of heat conductive metal (e.g. aluminium) so as to improve heat transfer between the boiling passages 4 and the condensing passages 6. Rather than employing a single piece of finning 14 extending from top to bottom of each boiling passage 4, a vertical array of several identical pieces 15 is used instead for ease of handling. Typically, each piece of finning 14 is of the same height as each individual second sheet 10. The pieces of finning 14 are disposed in the passages 2 such that their corrugations 16 all extend vertically. The wave-shaped members 14 thus divide each boiling passage 4 into a multiplicity of vertical sub-channels 18. In each boiling passage 4 the pieces of finning 14 are bonded at each of their apices to the respective plates 2. A fluid-tight sealing is provided at each bond such that liquid cannot, in operation, flow directly across a plate 2 from one sub-channel 18 to an adjacent sub-channel 18.

[0020] The finning 14 may be sinusoidal. Alternatively, the corrugations 16 may be closer together than in a pure sine wave. It is preferred that the finning has curved apices, but they can alternatively be flat. Typically, the number of fins per 100 mm is in the range of 20 to 100, preferably in the range of 50 to 75. Each corrugation 16 engages a row of baffles 12. The engagement is preferably fluid-tight at each corner 20 defined between a plate 2 and finning 14 engaging the plate 2. Accordingly, in operation, liquid flowing down a plate 2 in a corner 20 is constrained to flow out of the corner 20 each time it encounters a baffle 12. Typically, each baffle 12 extends from a tenth to a third of the way into the sub-channel 18 with which it is associated.

[0021] The finning 14 preferably has a multiplicity of small perforations 17 so as to enable vapour to flow from one sub-channel 18 to an adjacent one. The open area may comprise 20 to 40% of the total area of the finning 14.

[0022] As shown in Figures 1 and 3, the top of each boiling passage 4 is open and communicates with a distributor 22 of liquefied gas to be boiled. The liquefied gas may, for example, be liquid oxygen. The construction of the distributor 22 will be described below. The bottom of each boiling passage 4 is also open and permits any unboiled liquefied gas to leave the heat exchanger under gravity. As shown, particularly in Figure 5, each boiling passage 4 is closed at its sides by vertical spacer bars 24. Both spacer bars 24 are formed with a recess to receive the sheets 10.

[0023] Each condensing passage 6 is generally similar to the boiling passages 4, containing finning or wave shaped members 26 of heat conductive metal (e.g. aluminium) so as to enhance the rate of heat transfer between the boiling passages 4 and the condensing passages 6. The wave shaped members 26 are arranged in each condensing passage 6 in end to end relationship so as to form a vertical array.

[0024] Each wave-shaped member 26 preferably has perforations 30 formed therethrough and is disposed such that its corrugations extend vertically. Each array 28 of wave-shaped members (or finning) 26 has its top edge disposed below the top of the condensing passage 6 in which it is located. Referring to Figures 1 and 4, in particular, this enables perforate finning 32 with inclined corrugations to be provided in the passages 6 for the purpose of distributing in a uniform manner gas to be condensed to the passages 6. This gas may, for example, be nitrogen. Similarly, each array 28 of finning 26 has its bottom edge disposed above the bottom of the condensing passage 6 in which it is located. This also enables perforate finning 34 with inclined corrugations to be provided in the passages 6 for the purpose of conducting resulting condensed gas out of the heat exchanger. The arrangement of the finning 32 and 34 will be described below.

[0025] The finning 26 is generally similar to the finning 14 employed in the boiling passages 4, and in each condensing passage 6 the finning is bonded at each apex to a respective plate 2. No baffles, corresponding to the baffles 12, are provided in the condensing passages 6.

[0026] Entry of fluid to and exit of fluid from the condensing passage 6 is from opposite sides of the heat exchanger. Accordingly, each condensing passage 6 is closed at its bottom by horizontal end bar 36 and at its top by a horizontal end bar 38. In addition, each condensing passage 6 is sealed at its sides by vertical bars 40, as shown in Figures 4 and 5 (although plates may be used instead). The bars 40 are arranged so as to permit the inlet of fluid to and the flow of fluid out of the condensing passages 6.

[0027] Liquefied gas to be boiled in the heat exchanger is able to flow through a header 42 which has an inlet 44 (see Figure 4) and which communicates with the distributor 22. The distributor 22 comprises a reservoir 46 which is located above the passages 4 and 6, is open at its top, and is parallelepipedal in shape. As shown in Figure 1 the base of the reservoir 46 is provided by a horizontal plate 50 having orifices 52 therein. The plate 50 is spaced apart from the top of the passages 4 and 6. The plate 50 is provided with a series of regularly-spaced elongate baffles 54 each extending downwards therefrom and from one side to the other of the heat exchanger. Each baffle 54 starts along the centre line of a respective boiling passage 4. The orifices 52 are arranged in rows which are staggered in respect to the baffles 54. In operation, each row of orifices 52 is constrained by neighbouring baffles 54 to communicate with one boiling passage 4 to the left of it and another boiling passage 4 to the right of it. Each orifice 52 is typically slit-shaped. The orifices 52 regulate the flow of liq-

uefied gas into the boiling passages 2 against the upward passage of vapour therethrough. Liquid weeps through the orifices 52 against the flow of vapour. The height of liquefied gas in the reservoir 46 determines the weep rate assuming that there is a uniform upward flow of vapour through each boiling passage 4. Should the rate of liquid vaporification in any particular boiling passage fall for any reason, the rate of weeping into that passage 4 increases thereby increasing the rate of vaporisation again. Accordingly, the distributor 22 tends to be self-adjusting so as to give a uniform rate of vaporisation in each boiling passage 4. Further information about the construction and operation of such a distributor 22 is given in EP-A- 780 646. The invention is not however limited by the choice of distributor. Any suitable distributor may be used, for example either those disclosed in EP-A- 797 065 or those disclosed in US-RE-33 026.

[0028] A header 60 (see Figure 4) is provided for the introduction into the heat exchanger of gas to be condensed. The header 60 has an inlet 62 and communicates, via hardway finning 64, whose corrugations run horizontally, and the finning 31, which has inclined corrugations, with the top of the condensing passages 6. Gaseous fluid is guided by the finning 64 and the finning 32 into the condensing passages 6. All the gas is condensed by heat exchange with the liquid being vaporised in the boiling passages. The resulting liquid is guided by hardway finning 66 and the finning 34, which has inclined corrugations, to an outlet header 68 having a common outlet pipe 70.

[0029] In operation of the heat exchanger illustrated in the drawings as a reboiler-condenser that places the top of the higher pressure column (not shown) in heat exchanger relationship with the bottom of the lower pressure column (not shown) of a double rectification column (not shown) for the rectification of air, liquid oxygen is supplied at a chosen rate and at a pressure of about 1.3 bar absolute to the top of the boiling passages 4 and gaseous nitrogen at a chosen rate and at a pressure typically in the range of 5 to 6 bar to the top of the condensing passages 6. The distributor 22 performs the function of ensuring that for a given flow rate of liquid oxygen to the heat exchanger, liquid oxygen is fed at a uniform rate to each boiling passage 2 and that the rate of feed to any one boiling passage 2 does not substantially differ from that to any of the others. The rate is such that a thin, downwardly flowing, film of liquid oxygen is established on the boiling surfaces that are provided by the plates 2 and the finning 14. Gaseous nitrogen flows into the condensing passages 6 via the header 60, hardway finning 64, and the finning 31. The pressure of the nitrogen is selected such that the nitrogen has a temperature in the order of 1 to 2K above the boiling temperature of liquid oxygen. The nitrogen flowing downwardly through the condenser passages 6 exchanges heat with the liquid oxygen flowing downwardly through the boiling passages 4. As a result, the nitrogen condenses and some of the liquid oxygen boils. The nitrogen condenses as a thin film on the condensing surfaces of the plate 2 and the finning 26. The condenser nitrogen flows under gravity out of the heat exchanger through the outlet header 68.

[0030] Forces of surface tension and gravity tend to draw the liquid into the corners 20 of the sub-channels 18. The tendency is particularly marked with sharp corners of the kind that are formed between the plates and some conventional forms of filling, Once in the corners, the liquid tends to flow rapidly out of the heat exchanger because, it is believed, the volumetric flow rate is proportional to the film thickness raised to the third or fourth power. There is therefore a tendency for the central regions of the boiling surfaces on the plates 2 to become denuded of liquid oxygen. Although having a thicker film can be beneficial to the heat exchange (and it is for this reason that we prefer not to have any baffles in the condensing passages 6) it is important for reasons of avoiding an explosion hazard to prevent the creation of any local dry spots on the boiling surfaces. It has therefore been the practice in conventional downflow reboilers of liquid oxygen to operate them with such an excess of liquid oxygen that notwithstanding the above-mentioned effects which draw the liquid oxygen into the corners, there is always a sufficient flow rate of liquid oxygen in, for example, the central regions of the boiling surfaces on the plates to avoid any localised dryout. As a result, only about a half of the liquid oxygen flowing through the boiling passages at any one time is vaporised. Therefore, there is a need for a substantial recirculation pump to return at least some of the unboiled liquid oxygen to the top of the heat exchanger. (In some air separation plants, some or all of the liquid oxygen product is withdrawn from the lower pressure column in liquid state. As a result, there is reduced load on the reboiler-condenser. In other plants, however, the oxygen product is withdrawn from the lower pressure column entirely in gaseous state. Therefore, in these plants, the reboiler-condenser has to perform the dual role of providing the necessary flow of vapour up the column to enable efficient heat transfer to take place and of boiling the oxygen product. In these plants, the recirculation rate to the top of a downflow reboiler will be greater than in plants in which some or all of the oxygen product is withdrawn from the lower pressure column in liquid state).

[0031] In accordance with the invention, this problem is ameliorated by the provision of the baffles 12. In view of the sealing engagement made between the baffles 12 and the finning 14, liquid oxygen flowing in a corner 20 has each time it encounters a baffle 12 to flow out of the corner. The liquid oxygen will therefore find its way onto the surfaces of the finning engaging the baffle 12. As a result, build up of liquid oxygen in the corners is reduced. The forces of surface tension and gravity will of course tend to draw the thus diverted flow of liquid oxygen back into the corners. Indeed. the flow can, we believe, be restored to its previous thickness within a

distance of 10 mm or less. It is therefore desirable that the baffles 12 in each vertical array are spaced relatively close together as stated hereinabove.

[0032] Residual liquid oxygen is not boiled flows out of the bottom of the boiling passages 4. Most of the oxygen vapour exits via the distributor 22.

[0033] The apparatus according to the invention may also be used as a dephlegmator in which mass exchange as well as heat exchange takes place in the boiling passages 4 and in which the liquid which is fed therethrough is a mixture of two or more components. In a dephlagmator, the tendency of the liquid to flow into the corners of the sub-channels has the effect of reducing the range of liquid flow rates in which an adequate heat transfer co-efficient is maintained. Accordingly, since generally it will be necessary in the course of operation of the dephlegmator to vary the liquid flow rate quite considerably, it is necessary to design the dephlegmator for operation at the low heat transfer co-efficient, therefore making the dephlegmator much larger in size than it would otherwise be. By use of the baffles 12, however, the operating range of the boiling passages 2 at relatively high vapour mass fractions can be extended thereby making it possible to make the dephlegmator of smaller size. In other words, if the liquid is sucked into the corners defined between the fins and the plates it is no longer actively participating in mass transfer. By making possible operation with relatively low liquid flows into the corners, a dephlegmator according to the invention operates more efficiently than comparable known dephlegmators.

[0034] Referring now to Figure 6 of the drawings, there is illustrated therein a modification to the heat exchanger shown in Figures 1 to 5. Like parts in Figures 1 to 5 on the one hand and Figure 6 on the other hand are identified by the same reference numerals. The essence of the modification is that instead of the baffles 12 in the heat exchanger shown in Figures 1 to 5, dimples 112 are used instead. The function of the dimples 112 in the heat exchanger shown in Figure 6 is essentially the same as that of the baffles 12 in the heat exchanger shown in Figures 1 to 5.

[0035] The dimples 112 may be formed by a simple stamping operation. Their spacing is similar to that of the baffles 12 of the heat exchanger shown in Figures 1 to 5. However, each plate 2 is formed of a one-piece construction rather than of a two-piece construction. Manufacture of the heat exchanger is thereby simplified.

[0036] In a typical example, each dimple 112 may have a maximum depth of from 1 to 3mm. The spacing between dimples 112 in each vertical now thereof may be in the range of 5 to 10mm. The finning 14 may have a pitch of 7.5 fins per 2.5cm.

Claims

1. A heat exchanger comprising a multiplicity of vertical, elongate, generally parallelapipedal boiling or mass transfer channels each having a pair of main vertical walls down which liquid is able, in operation. to flow. wherein at least one of the said boiling or mass transfer channels has therein at least one wave-shaped member dividing the channel into a multiplicity of vertical sub-channels, each apex of the said wave-shaped member engaging an abutting main vertical wall, characterised in that at least one of the vertical walls has at least one vertical row of baffles or dimples extending into at least one of the sub-channels, each baffle or dimple having a shape such that it engages the said wave-shaped member at both the sub-channel corner regions defined between the main vertical wall from which the baffle or dimple extends and the said wave-shaped member itself.

2. A heat exchanger as claimed in claim 1, in which the baffles are inclined at an angle in the general direction of liquid flow, each baffle being at an angle of 45° to 85° to the vertical wall through which it extends.

3. A heat exchanger as claimed in claim 1 or claim 2, in which the baffles or dimples are uniformly spaced apart, and all the baffles or dimples are of identical size and shape.

4. A heat exchanger as claimed in claim 3 in which all the baffles are at the same angle to the general direction of liquid flow.

5. A heat exchanger as claimed in any one of the preceding claims, in which the baffles or dimples are relatively closely spaced in each row, being in the range of 4 to 10 mm apart.

6. A heat exchanger as claimed in any of the preceding claims, in which each main vertical wall comprises a first base sheet bonded to a complementary second sheet or array of second sheets, wherein the baffles extend from second sheet.

7. A heat exchanger as claimed in claim 6, in which the baffles take the form of tabs which are preformed by being stamped out of each second sheet.

8. A heat exchanger as claimed in any one of the preceding claims, in which the baffles in a row extending from any particular main vertical wall may be staggered in relation to the baffles in a neighbouring row extending from that vertical wall.

9. A heat exchanger as claimed in any one of the preceding claims, in which the rows of baffles in any particular main vertical wall are staggered in relation to the rows in the opposite main vertical wall.

10. A heat exchanger as claimed in any one of the preceding claims, in which the boiling or mass exchange passages are arranged alternately with passages through which a condensable gas is able to be passed.

11. A heat exchanger as claimed in any of the preceding claims, wherein the heat exchanger is of the plate-fin kind, the plates providing the said walls, and the fins providing the wave shaped members.

12. A heat exchanger as claimed in any one of the preceding claims, in which the boiling passages communicate with a source of liquid oxygen.

13. A heat exchanger as claimed in any one of claims 1 to 11, wherein the heat exchanger is adapted to a function as a dephlegmator.

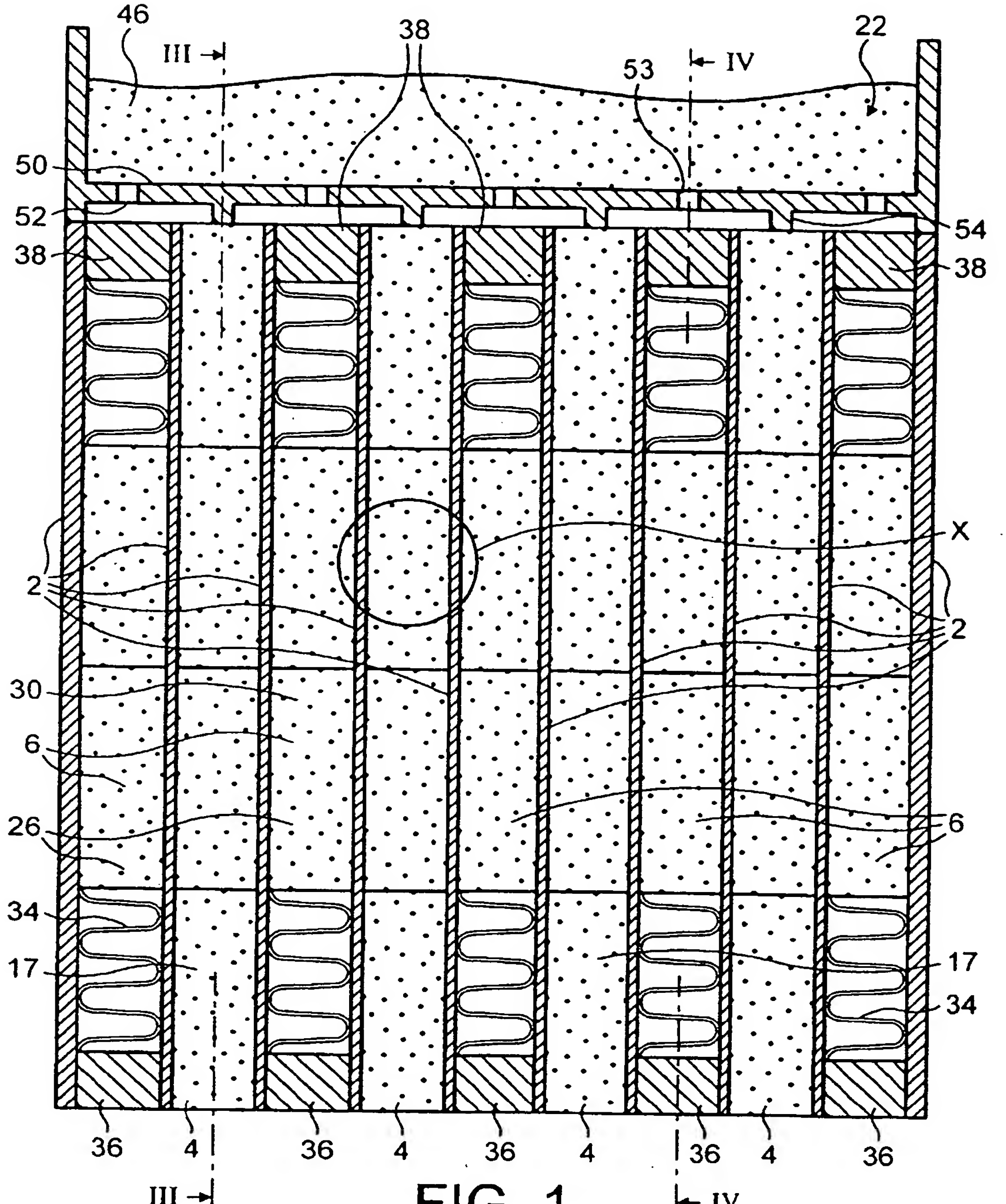
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FIG. 1

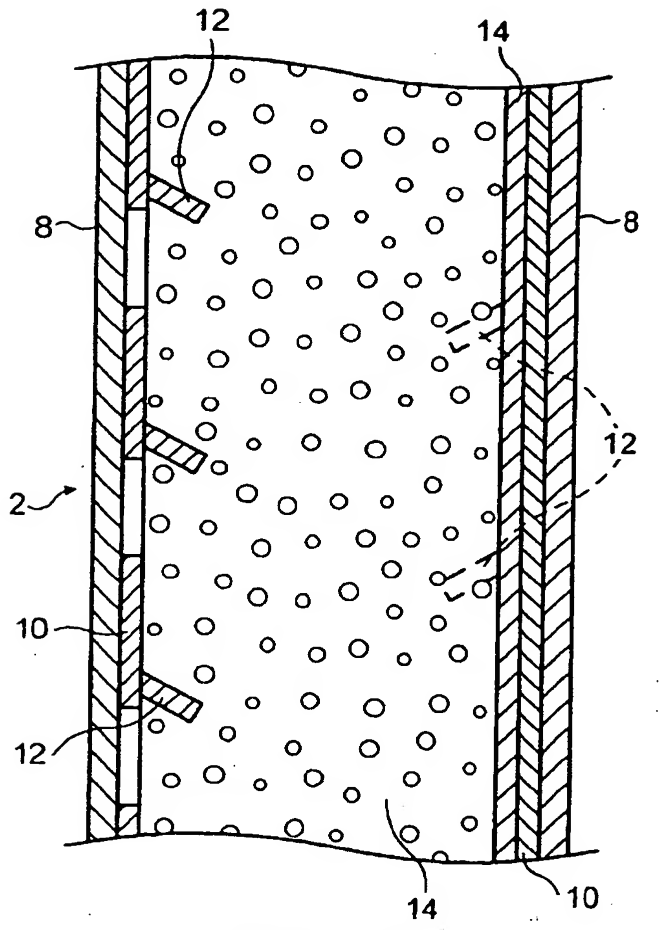

FIG. 2

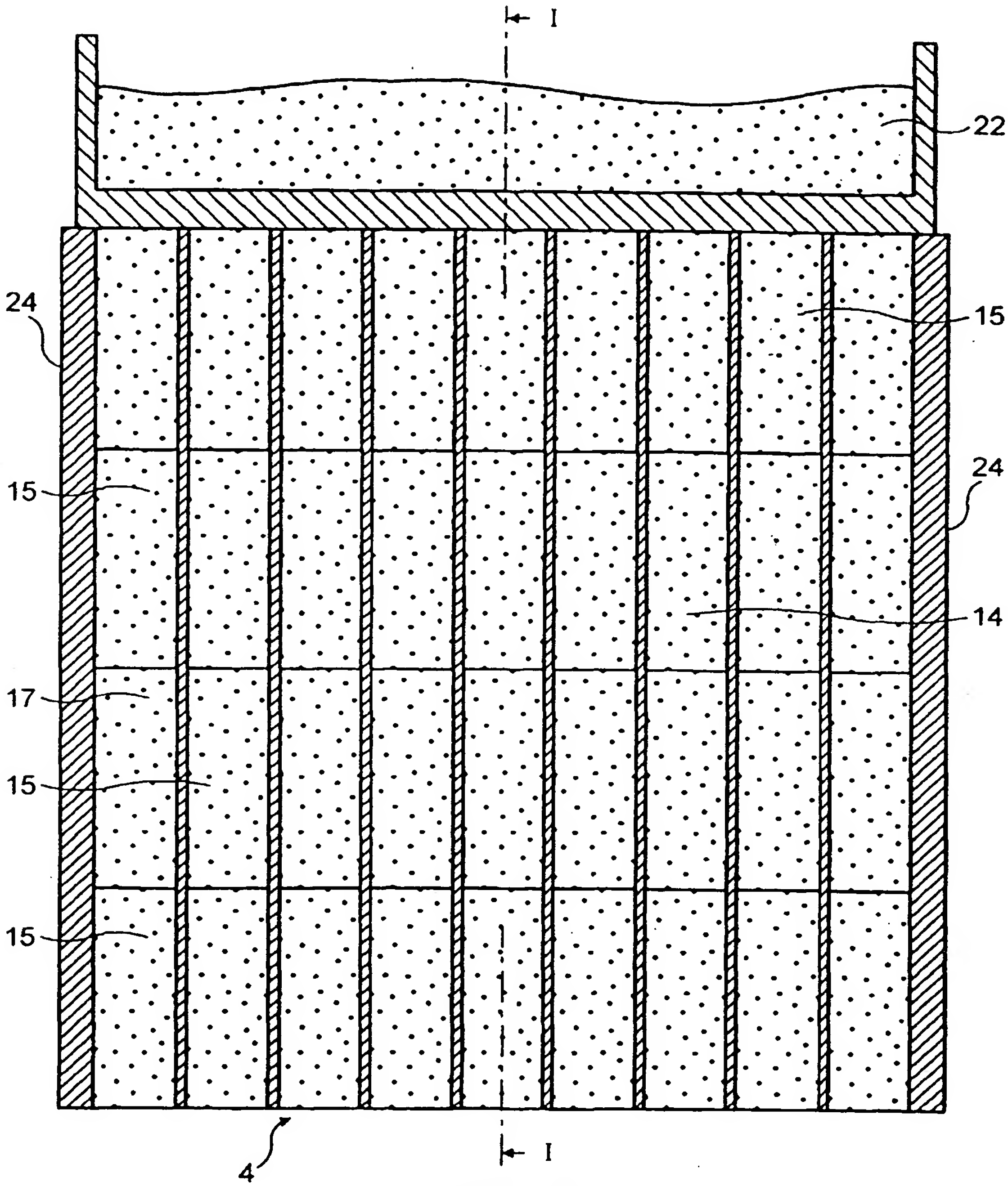

FIG. 3

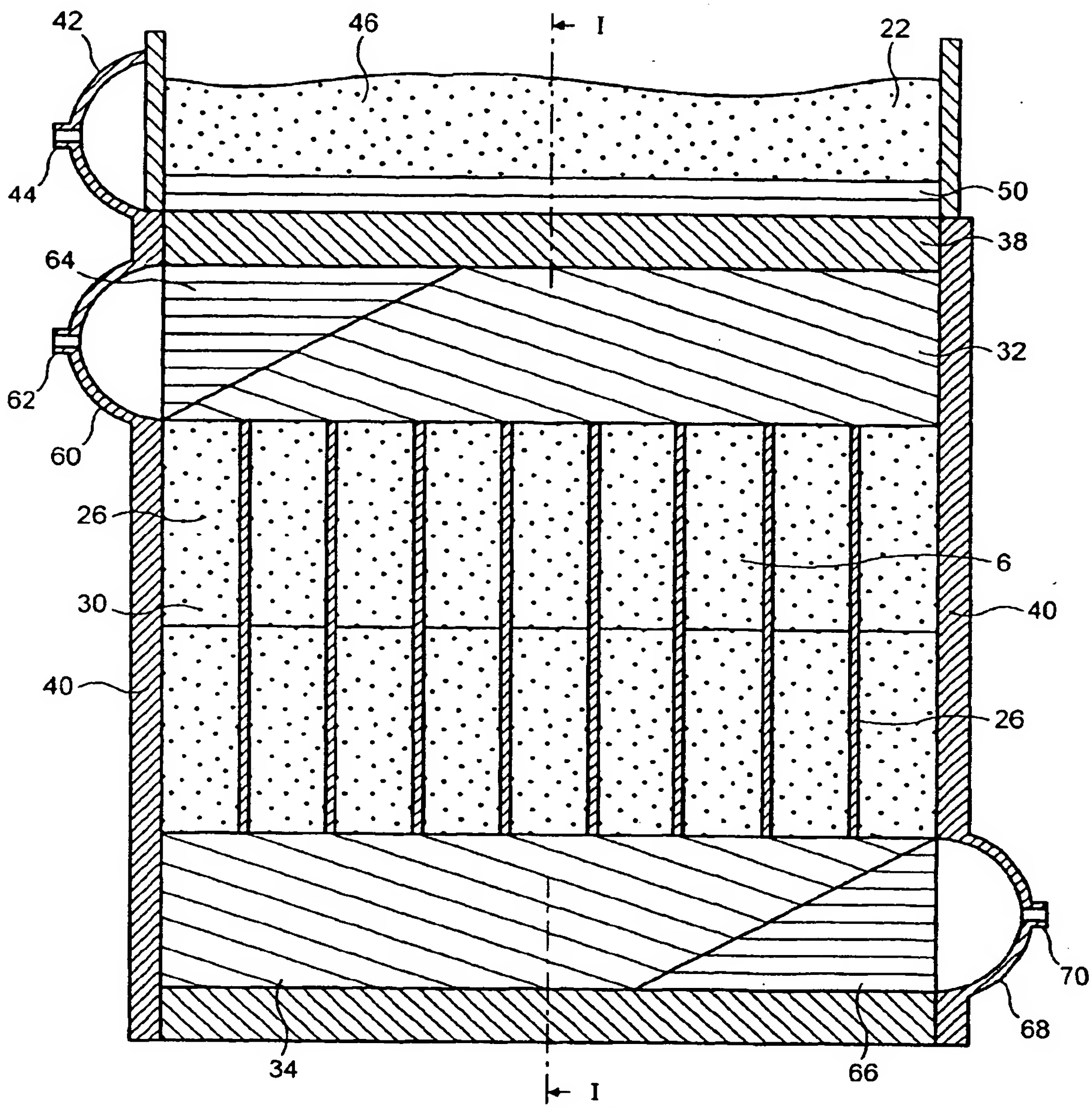

FIG. 4

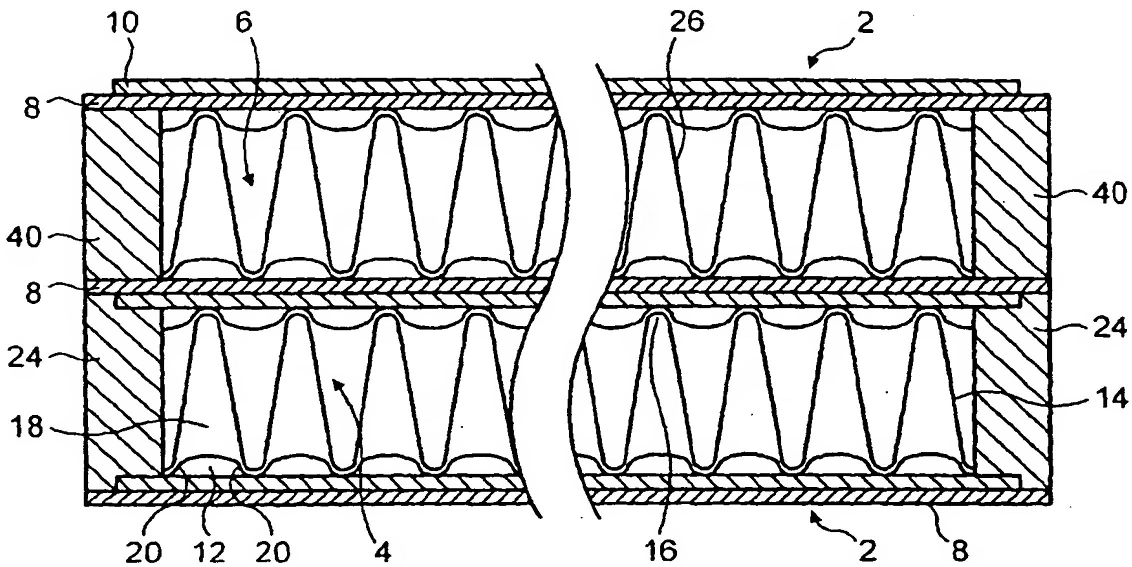

FIG. 5

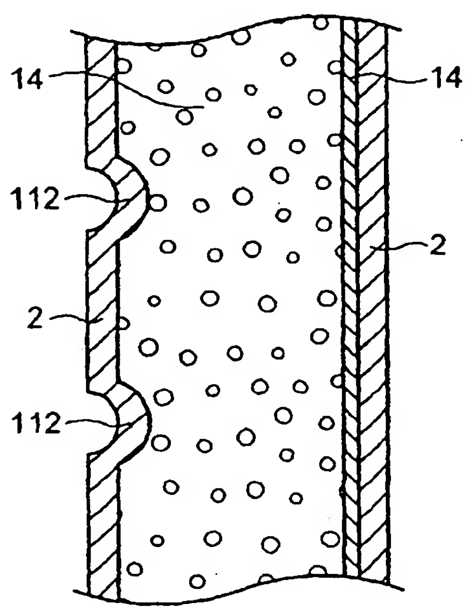

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 9604

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	GB 2 204 117 A (NAT NUCLEAR CORP LTD) 2 November 1988 (1988-11-02) * the whole document *	1	F25J3/00 F28F3/02 F28F13/06
A	US 5 975 503 A (LILLICO DOUGLAS ALEXANDER ET AL) 2 November 1999 (1999-11-02) * abstract; claims; figures * * column 2, line 6 - line 14 *	1	
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Place of search	Date of completion of the search	Examiner
THE HAGUE	16 February 2001	Lapeyrere, J

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